



THE INFLUENCE OF HEATHER ON SILVICULTURAL PRACTICE—AN APPRAISAL*

By D. C. MALCOLM

Department of Forestry and Natural Resources, University of Edinburgh

Summary

The widespread distribution of *Calluna* dominated vegetation types emphasises the silvicultural importance of the interaction between heather and young trees. The nature of the possible mechanisms of competition resulting in "heather check" of planted trees is examined and the silvicultural techniques available to overcome it are discussed.

Introduction

The vegetation of the land available for afforestation in Britain often includes *Calluna vulgaris* (L.) Hull., either in almost pure stands as on the drier heaths of the east, where it is maintained by periodical burning, or in association with a number of other species, such as *Eriophorum vaginatum* L., *Molinia coerulea* (L.) Moench and *Trichophorum caespitosum* (L.) Hartmann on the peats in the wetter areas. Gimingham (1972) has listed the main categories of heath communities in which *Calluna* occurs in Britain, N.W. Europe and S. Scandinavia and shows that the whole of the British Isles falls within the area in which *Calluna* may be the dominant species in a community.

A recent survey of the land reserved for planting by the Forestry Commission (Paterson, 1972) showed that about 55% of the existing vegetation comprised types in which *Calluna* was described as "frequent or dominant" and that in a further 14% it was "occasional."

The occurrence of *Calluna* on a wide range of site conditions, on soils varying from the occasional brown earth type through iron pan and peaty podsols, peaty gleys to deep oligotrophic peats, might suggest that it had little value for indicating site conditions. However it is the condition of the heather, whether it is vigorous, flowers freely or is stunted, that is important. Its condition together with the occurrence of other species in association indicate the cultivation and other ameliorative treatments that must be undertaken if satisfactory stands of tree species are to be established.

Vigorous heather is mostly confined to soils that are freely drained in at least their upper horizons, whereas on wetter soils, the gleys and peats, it usually forms a smaller proportion of the vegetation and is of low stature and unthrifty, indicating the need for drainage and fertilisation if tree root systems are to survive. These cultural treatments, performed for the benefit of the newly planted trees, also improve the conditions for the *Calluna* which normally responds rapidly and thus exacerbates the main problem that heather creates for the silviculturalist.

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Heather "check"

It has long been known that trees planted into dense swards of *Calluna* make slower progress than those on other vegetation types. While all tree species seem to suffer in association with *Calluna* some are much more "sensitive" than others. The invasion of heathlands by tree species indicates that at least some, notably Scots pine and the birches, are capable of survival and establishment, particularly if some physical disturbance temporarily reduces the dominance of the heather. On the other hand most productive tree species of interest to the forester enter a "checked" condition, in which they remain, so long as they are surrounded by the heather. Trees in "check" exhibit almost no growth and usually display symptoms of severe nitrogen deficiency and have particularly poor root development. Handley (1963) has summarised the literature on the phenomenon from its first description by Müller in 1897 on the Danish heaths. Experience from West Europe and Britain confirms that pines and larches are less affected than the economically desirable spruces and firs. In Britain Sitka spruce (*Picea sitchensis* (Bong.) Carr.) has become the most important species used in afforestation during the last two decades, mainly because of its high potential productivity and its ability to tolerate exposed conditions. The extension of its use on to the drier heaths and poorer peats on which *Calluna* is or becomes dominant after drainage has emphasised the problem of heather check.

From the beginning it was recognised that the *Calluna* itself was the source of the problem and not the mor humus or competition for nutrients or water. On the generally nutrient poor and dry heathland soils these other factors do not, of course, encourage rapid early growth of mesophilous species such as the spruces, but on *Calluna*-free sites with similar conditions they do not "check" in the same way. It was also noted early that species sensitive to heather competition did not develop the much branched mycorrhizal root systems typical of the normal condition of actively growing plants. This led to the speculation that some factor closely associated with the *Calluna* plant prevented the development of the ectomycorrhizal association in the trees. Empirical research by the Forestry Commission had shown in the 1950s (Wetherell, 1953; Leyton, 1955) that mulching of checked plants with cut *Calluna* was capable of relieving the "check" condition. Zehetmayr (1960) in his survey of afforestation experiments up to that time considered mulching to be the "most certain treatment" for the stimulation of checked plantations although he recognised its impracticability on a large scale.

The ability of *Calluna* mulch to stimulate growth seemed to rule out the possibility that *Calluna* litter was the source of the problem and led Handley (1963) to investigate the effects of *Calluna* mor on the growth and development of a range of mycorrhizae forming fungi. He found that aqueous extracts of mor from stands of vigorous *Calluna* could inhibit the growth of most of the fungi tested whereas extracts from other soils of similar acidity and nutritional status did not. The inhibition was less pronounced where the mor sample came from shaded *Calluna* or was less acid. There seemed to be some variation in the resistance of different





fungi to the inhibitory factor and in particular with *Boletus scaber* Bull. which occurs on *Calluna* heathland, suggesting that strains of this fungus could form ectomycorrhizal associations with trees (pines) that apparently tolerate *Calluna* competition. Handley (1963) reached the conclusion that the source of the inhibitory factor must be the *Calluna* root systems and thought the *Calluna* endophyte probably produced antibiotic substances which were excreted into the soil around the root. In support of this theory he quoted Stalder and Schütz who demonstrated with ericaceous plants that application of mineral N destroyed their mycorrhizal association resulting in pathogenic attack on their root systems. This complements some observations of the reduction of the *Calluna* effect on mineral soils richer in available N and after N fertilisation.

Handley's work did not achieve immediate acceptance and as late as 1970 Björkman (1970) suggested that the direct competition of *Calluna* should not be neglected. The ability of "heather sensitive" species to compete with other vegetation, some of which is more exacting in its nutrient and water demands than *Calluna*, would seem however to relegate direct competition to a somewhat lesser role.

Some observations made in a Forestry Commission experiment help to illuminate this. The experiment was designed to examine the effect of N on the growth of Sitka spruce on a deep oligotrophic peat in Mabie Forest in Dumfriesshire by applying urea (168 kg N/ha) either annually (NA) or periodically (NP). The plough-drained bog was dominated by *Calluna* except on the top of the upturned planting turves. Superimposed on the nitrogen treatments control of the *Calluna* by 2, 4-D ester was tested, the herbicide being applied in the third year after planting (1969). All treatments received standard P and K applications.

The results of measurements, based on 30 sample trees per treatment, made one year after the destruction of *Calluna* are given in Fig. 1. The nutrient content of both current year tree and *Calluna* foliage was determined and are shown in Fig. 2 while the effects of urea on the peat have been described elsewhere (Malcolm, 1972).

From Fig. 1, the height growth made by the treatments receiving urea applications was much the same as the control plots after three years and before the herbicide treatment was effective. The following year, the elimination of *Calluna* led to a spectacular increase in leader extension, particularly of the OW plots receiving no nitrogen. It is thought that the relatively smaller response of the NAW treatments was due to an imbalance developing in the N:P:K ratio in the trees. The other interesting effect due to the NA treatment is the significantly greater lateral spread of the tree crowns, which might result in earlier suppression of the heather.

These results suggest that the amount of growth made is not closely related to the availability of mineral N in this peat and that sufficient N is available, at least for the early years, if the *Calluna* is removed. In the non-weeded treatments there was no statistically significant difference in height growth between annual or periodic N application and the control (L).



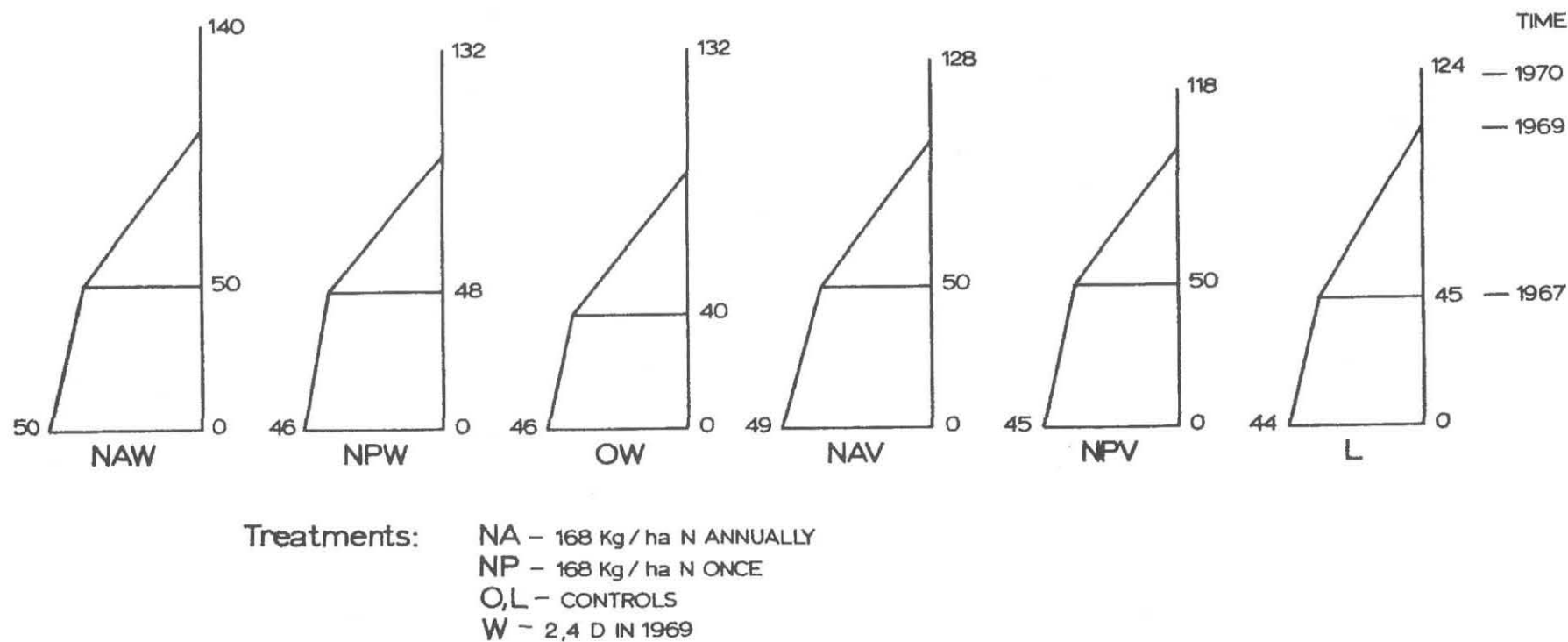


FIG. 1 MEAN TREE DIMENSIONS (cm)

Vertical axis—height extension.
Lower horizontal axis—total crown radius.
Upper horizontal axis—radius of the 1968 whorl.



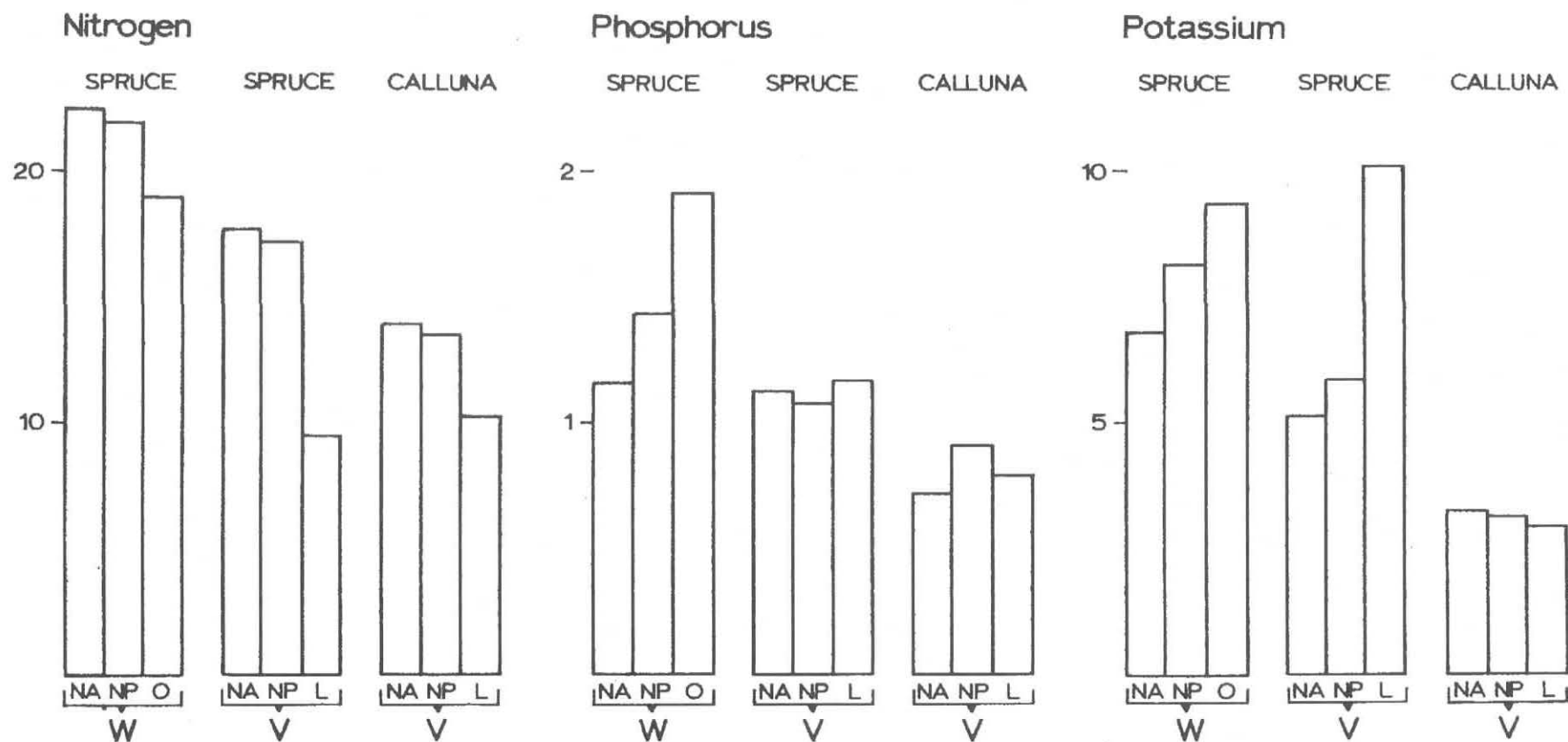


FIG. 2 CURRENT FOLIAGE CONCENTRATIONS—MG/G OVEN DRY WEIGHT. Racks Moss, Jan. 1971
(all values based on 30 samples)





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On the other hand the nitrogen concentration of the current year's foliage (Fig. 2) demonstrates that in the heather dominated control plots (L) the spruce is not an effective competitor and an appreciable amount of the added N is absorbed by the *Calluna*. The doubled concentration in the foliage of the trees freed from *Calluna* (OW) may be due partly to the release of N in the dead *Calluna* tissue although this source is generally thought not to be immediately available (Handley, 1954).

Both the P and K concentrations in the weeded plots with applied N are depressed although there is a suggestion that release from *Calluna* results in improved uptake and there is some evidence for direct competition in respect of P (OW v. L), despite the spot application of this fertiliser round the trees. There appears to be no effect of release from *Calluna* on K uptake (OW v. L) without added N. Similar results from a companion experiment in Borgie Forest have been given by Binns et al (1973). It can be concluded from these data that, on this peat type, the application of N in the form of urea does not completely release Sitka spruce from the slower growth associated with *Calluna* even though the concentration of N in the needles is raised above the accepted deficiency level. The *Calluna* effect is thus not simply one of competition for nitrogen.

The relative proportions of mineral N in the peat were determined as 22:7:1 for NAW, NPW and OW respectively. The presence of these large amounts of mineral nitrogen does not seem to cause any reduction in vigour of *Calluna*, as has sometimes been suggested, although high concentrations of ammonia must arise on the hydrolysis of the urea. These might have toxic effects in themselves while also increasing the pH of the peat. The NA plots had a mean pH value of 5.0, occasionally reaching 5.8, compared to pH 3.9–4.0 in the control plots, but both these values lie within the range tolerated by *Calluna* (Gimingham, 1972). Handley (1963) concluded however that the inhibitory factor was less effective when extracted from *Calluna* soils that were less acid. Further evidence on the *Calluna* "inhibition" has been presented by Robinson (1971, 1972) who, following up Handley's work, demonstrated *in vitro* that the effects observed were due to a phytotoxin derived from *Calluna* litter and a supposed antibiotic which was derivable both from *Calluna* mor humus and roots. Robinson tested a range of fungi and was able to show that while a specialised ectomycorrhizal associate like *Amanita muscaria* Pers. was severely inhibited in the presence of *Calluna* root washings this was not true for the *Calluna* endophyte or a saprophyte, *Hypholoma fasciculare* Quél. He was however unable to determine whether the endophyte, the *Calluna* root or both in association were responsible for the antibiotic production. Here too the role of pH was important, as the effect was much less marked at pH 6.5 than pH 3.9.

The evidence now seems strong that the attainment and maintenance of dominance by vigorous *Calluna* on acid heathland soils is achieved through its allelopathic effect on potential competitors which have to rely on ectomycorrhizal associations for adequate nutrition. The ecological implications of this allelopathy for the relationships between *Calluna* and other species of the heathlands is as yet uninvestigated. In the context





of the establishment of tree species in *Calluna* dominated vegetation however, it is important to note that the effect is not absolute but decreases with reduction in soil acidity, and the loss of vigour by *Calluna* through shading or senescence.

Silvicultural practice

If it is accepted that *Calluna* dominated sites are suitable for afforestation, and without them the scope for extending the forest area in this country would be minimal, the question is how to avoid or control the influence of heather on the planted trees. This can be achieved through a combination of silvicultural and management planning which involves many of the techniques which have been developed over the last 50 years in this country.

(a) SPECIES SELECTION. It is perhaps not surprising that the early successional or pioneer species such as pines, birches and larches should show least inhibition by *Calluna*. If the forester were satisfied with initial stands of these species then the *Calluna* problem would be greatly reduced. However experience indicates that many site types are capable of growing species in the first rotation which are potentially of much higher productivity. In addition many sites available for afforestation are exposed and at relatively high altitudes or with high cloud incidence for which the native Scots pine and the larches are not suitable. It is on these sites that, above all, Sitka spruce, given suitable cultural treatments, has demonstrated its ability to establish readily and survive. The other species of high productivity such as the Silver and Douglas firs, Norway spruce and Western hemlock are less readily established outwith a forest environment at moderate elevations and are markedly heather "sensitive" too. The choice for many sites is therefore restricted to Sitka spruce or the inexacting lodgepole pine (*Pinus contorta* Loud.) and these two species have become predominant in British planting. Marketing conditions and the higher potential yields of Sitka spruce have further encouraged its use on sites where not only is *Calluna* a problem but other physical and chemical properties of the site may be limiting. In these conditions, such as the deep oligotrophic peats or the drier heathlands of the east, traditionally the domain of Scots pine, the long term future of Sitka spruce is not yet assured biologically and therefore financially. Silviculturally there is therefore a choice between planting a pine (Lodgepole or Scots), thereby reducing the need to control *Calluna* and minimising the use of resources for other cultural treatments while accepting a low yield or, by initially ameliorating the site conditions, eliminating the *Calluna* and meeting any further requirements, anticipate a higher yield from spruce. A further possibility is the adoption of a mixture of species.

(b) MIXTURES. Before the development of machines able to undertake intensive cultivation and before the advent of effective herbicides, mixtures provided the main hope of establishing spruce on *Calluna*. Mixtures can be of several types; the species to be mixed may be planted at the same time in varying proportions and patterns, from intimate mixing by





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individual plants or rows, by bands to groups. Alternatively the major species may be introduced after the "nurse" species has become established and is providing some climatic amelioration. All the possible variants have been tested and are described by Zehetmayr (1960). The main aim is to achieve suppression of *Calluna* by an insensitive species, almost always Scots or lodgepole pine, thereby allowing the more productive element, usually spruce, to overtake the nurse and become the main stand. The idea is based on the observation that spruce frequently develops long unbranched rope-like roots which explore the upper organic horizons until they encounter a *Calluna* free zone such as the litter under a developing pine, where they branch freely and develop the mycorrhizal habit. In group mixtures the edge trees achieve this first and the spruce group develops a characteristic "bowl" shape as the effect spreads in towards the centre until canopy is closed and the *Calluna* is suppressed. Obviously the more intimately the pine is mixed through the spruce the more uniformly and rapidly will the latter respond.

Unfortunately in practice mixtures have rarely progressed as planned. Firstly, on the poorest sites the response of the spruce is delayed so that they become suppressed by the pine nurses entailing the removal or cutting back of the latter before they reach saleable sizes. Secondly on sites where *Calluna* is not entirely dominant, occurring as patches through the vegetation, the spruce grows away rapidly dominating the pine. The third and most important aspect is the need for basic cultivation to improve the aeration and internal soil drainage on thin iron-pan podsoles. This has usually been done by spaced furrow ploughing with the trees being planted on the ridge thus delaying, if not preventing, the spread of roots across the furrow and under the "nurse" species in row or band mixtures. The use of leguminous shrubs has also been tried to improve the N status and suppress *Calluna* with some success but here again intensive work is required to release the main species from the competition of the nurse which itself also often requires fertilisation and soil working to become established.

In brief, mixtures can achieve the removal of the heather problem and are silviculturally practicable but create serious management problems which make their use on a large scale less desirable.

(c) CULTIVATION. The aims of cultivation include amelioration of the soil physical conditions, the suppression of competing vegetation and the release of nutrients through decomposition of both vegetation and accumulated organic matter. While the main purpose is to improve the site for the newly planted trees, cultivation also stimulates the growth of *Calluna* only partially destroyed by the standard spaced furrow ploughing techniques. Recolonisation is rapid in these circumstances giving the trees too short a period, often less than three years, in which to develop crowns that can shade out the encroaching *Calluna*. Probably the only form of cultivation to give some heather control is deep complete ploughing which, in an experiment on poor heathland at Teindland, had only 30%





Calluna cover after six years compared to 80% on spaced furrow ploughing (Thompson and Neustein, 1973).

(d) FERTILISATION. Many sites where *Calluna* is a problem are inherently infertile and a precondition for satisfactory tree growth is the addition of phosphorus, and on peats, potassium. Because of this basic requirement it is difficult to separate the nutritional effect from that due to *Calluna*. The evidence available suggests that on deep peats addition of fertiliser does little to relieve *Calluna* "check" whereas on peaty podsols and peaty gleys, previously with a proportion of *Molinia coerulea* in the vegetation, the colonisation by *Calluna* may be overcome by applications of PK fertilisers about five years after planting (Thompson, 1972). On the more typical *Calluna* heathland iron pan podsols, nitrogen appears to be the most limiting nutrient to start with though later on the other nutrients also may be involved (Mackenzie, 1974a). In recent years the aerial application of urea N has been increasingly used as management has sought an economic means of avoiding *Calluna* check developing over large areas of newly planted ground.

(e) HERBICIDES. *Calluna* is susceptible to a number of the chemical preparations now marketed as herbicides. Of these perhaps paraquat and 2, 4-D are the best known and the latter is by far the more important. It has been demonstrated that a moderate application of about 4 kg 2,4-D acid/ha can achieve over 80% control of *Calluna*. It might be thought therefore that the *Calluna* problem in forestry was solved. Unfortunately while the technique has been demonstrated to be extremely effective, it has a number of disadvantages from the management point of view. In the first place, to be effective the heather should be vigorous and in active growth at the time of application. Secondly, the treated trees are damaged if they too are in active growth: thus the application has preferably to be made soon after cessation of height growth for crops less than one metre in height, *i.e.* during August for most conifers, although lodgepole pine is highly sensitive at any time. A measure of damage to the planted trees must be accepted and this is normally small if the herbicide is applied skilfully. Not only is there a management constraint in timing the application as when 2,4-D is applied by knapsack or mist-blower ample water supplies are required and when applied by ultra low volume spraying particular attention must be paid to wind and temperature conditions. Temperature is important in relation to the activity of the sprayed *Calluna*, the viscosity of the spray and vaporisation of the spray droplets, while wind affects drift control. With these features in mind a recent study based on hourly climatic data for Eskdalemuir over the spraying "seasons" for 1966-70 indicated only about 25% of working hours were suitable (Karas, 1974). These constraints are important as it is estimated that up to 8000 ha/yr potentially require *Calluna* control (Mackenzie, 1974b) so that attainment of such target areas becomes a management problem. However, the technique is so useful, particularly on the unflushed peat soils, that its use will rapidly extend beyond the estimated 2500 ha treated in 1972 (Mackenzie, 1974b).





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(f) COMBINED TREATMENTS. Although the various aspects of dealing with the *Calluna* "check" problem in afforestation have been discussed here separately, they are rarely so used in practice. The combination of techniques the forester uses will be related to the site conditions and will be conditioned by other management and economic factors.

The choice of species and cultivation treatments usually prescribe the importance to be attached to the *Calluna*. If the species chosen is heather "sensitive" and planted pure on normal spaced furrow planting the use of fertiliser and herbicide is indicated.

The interaction of these treatments is the subject of much current research. It has been shown, for example, that application of fertilisers prior to 2,4-D spraying can improve the control, presumably due to stimulation of the *Calluna*. Similarly the destruction of the *Calluna* releases additional nutrients into the pool available to the trees although this is likely to be a short term effect (Binns et al, 1973). Recently Mackenzie (1974a) has shown from experiments in east Scotland that on peaty iron pan soils a balanced NPK application (172 kg N: 50 kg P: 100 kg K/ha) can be effective in accelerating the early growth of Sitka spruce, although the addition of a herbicide treatment further improved performance particularly on the poorer sites and on two sites suggested that the nitrogen component is not necessary at an early stage.

Conclusion

The influence of man on the origin and development of *Calulna* dominated vegetation types has been pieced together from archaeological and ecological evidence and discussed in detail by Gimingham (1972). The heathlands are clearly man made and in a sense degraded and possibly unstable systems. The dominance of *Calluna* is largely maintained by man through his usage but this species appears to have an inherent advantage, through its allelopathic effects, in its competition with other potentially dominating species. To break this dominance the forester, by his cultural treatments, must reverse centuries of soil evolution and nutrient loss. In so doing he, in effect, temporarily increases the *Calluna* problem by extending heathland conditions into moister climates and soil types. On the drier heathlands of the east the successful transformation to forest is assured if inexacting *Calluna* tolerant species are selected and the same is probably true of the oligotrophic peats. The extension of the use of spruce on to these impoverished sites is still subject to doubts about the input of fertiliser and cultural treatment required.

The necessary effort to overcome the *Calluna* problem has however led to considerable improvements on these sites, improvements which are unlikely to disappear over long periods even though one mor humus vegetation type has been replaced by another. The transformation from heathland to forest has, of course, many other effects not necessarily confined to the areas planted. In the process of breaking *Calluna* dominance the forester is setting in train a long series of complex ecological changes that demand his close attention. It is eighty years since P. E. Müller first investigated the relationship between *Calluna* and the trees





on the Danish heaths. Since then the challenge of *Calluna* has been a dominating influence on the development of silvicultural practice in Britain.

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